Active Microfluidic Mixer with Fully-Differential Rotary Blades

Licheng Xiao, Advisor: Xingguo Xiong
Department of Electrical Engineering, University of Bridgeport, Bridgeport, CT 06604

Abstract

Mixing of microfluidic flows is difficult due to the fact that microfluid is generally laminar flow and turbulence is not enough. To improve the mixing of microfluid, passive or active microfluidic mixers are developed. Active micromixers need external energy input, but generally result in better mixing outcome compared to passive micromixers. In this poster, an active rotary microfluidic mixer with four rotary blades is designed. It has three inlets and one outlet. The four rotary blades introduce turbulence of the microfluid to help improve the mixing. The four rotary blades are arranged to form a fully differential structure. They can be activated to rotate clockwise, counter-clockwise or with a combination of both. The shape of the micromixer is custom-designed to reduce the dead angle compared to traditional cylinder mixer.

Introduction

Micromixer is a device used to mix different microfluids. In this research, an active microfluidic mixer with fully-differential rotary blades is proposed. Its octagonal chamber and fully differential blades design achieve better mixing efficiency. COMSOL simulation is used to simulate the concentration of the output flow and the mixing efficiency is calculated. The relationship between the mixing efficiency and different rotation schemes of the microblades as well as their rotation velocities are investigated. In order to find out how the fully-differential blades design improves the mixing efficiency, we designed the same microfluidic mixer without any rotary blades, with a single rotary blade and with four fully-differential rotary blades. COMSOL simulation results show that the mixing efficiency of fully-differential design is superior to single rotary blade design, which is in turn superior to the design without rotary blade. This verifies the fully-differential design leads to improved mixing efficiency of the micromixer. The proposed micromixer can be used in lab-on-a-chip, micro drug delivery system and other microfluidic devices where mixing of microfluidic flows is needed.

Micromixer Design

In this poster, we designed the micromixer using COMSOL in order to simulate the performance. It consists of three inlets, one outlet, a mixing chamber and four rotating blades. The blades can be activated to rotate clockwise or counter-clockwise. COMSOL Particle Tracing method is used to simulate the microfluid behavior of the mixer. The design/simulation parameters of the micromixer are listed in Table 1.

Table 1. Micromixer Design Parameters

Micro Mixer Design/Simulation Parameters	
Chamber inner diameter	3mm
Inlets width/height	0.35mm/0.5mm
Outlet width/height	0.35mm/0.5mm
Blades width/height	0.2mm/1.8mm
Inlet Particle Injection number per release	50
Ramp (rm1) slope	100
Inlet velocity	0.02[m/s]*rm1(t[1/s])
Inlet pressure	0 Pa
Drag force velocity field	Rmspf/fp1

Micromixer Design

The structure design of the active micromixer with four rotary blades is shown in Figure 1. The four blades can be set to rotating/clockwise with different rotation schemes. The rotary parameters (direction and speed) of one rotation scheme of the blades are listed in Table 2.

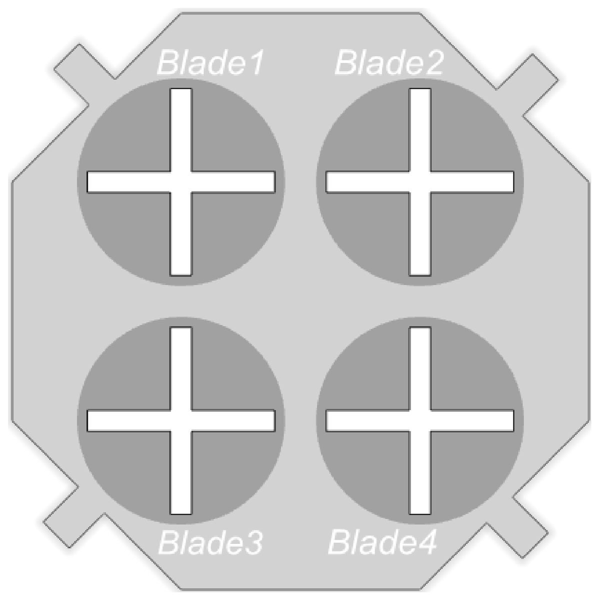
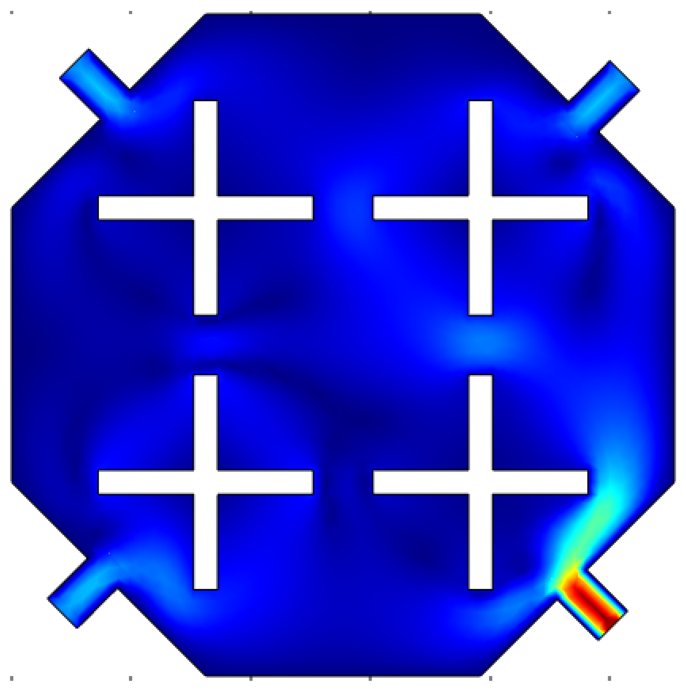


Fig 1. Micromixer design

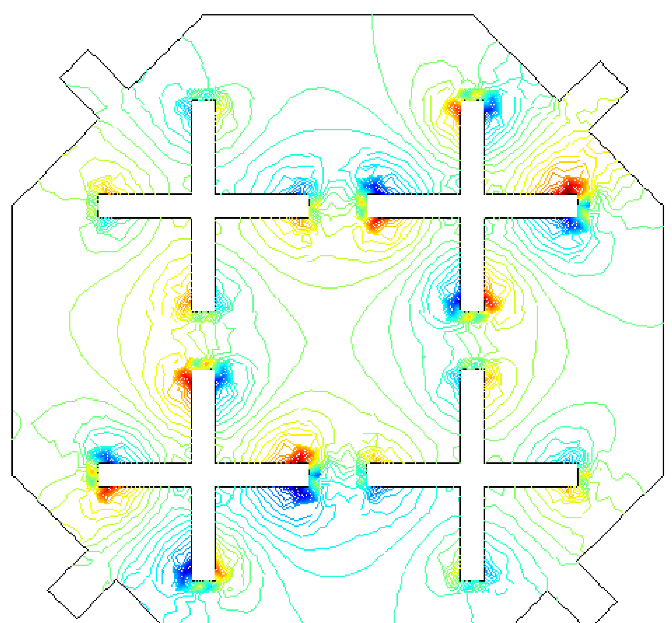
Table 2. Rotary Parameters

Rotary Parameters	
Blade 1	Clockwise 1 revolution/sec
Blade 2	Counterclockwise 2 revolution/sec
Blade 3	Counterclockwise 2 revolution/sec
Blade 4	Clockwise 1 revolution/sec

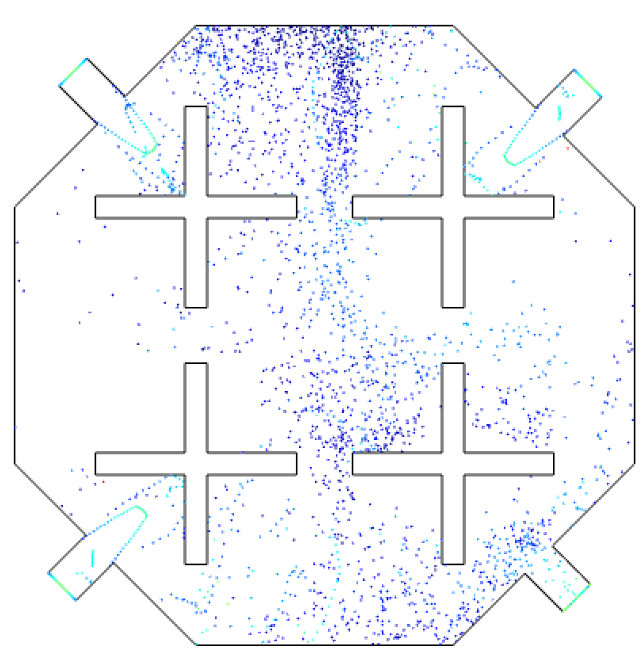
COMSOL Simulation Results



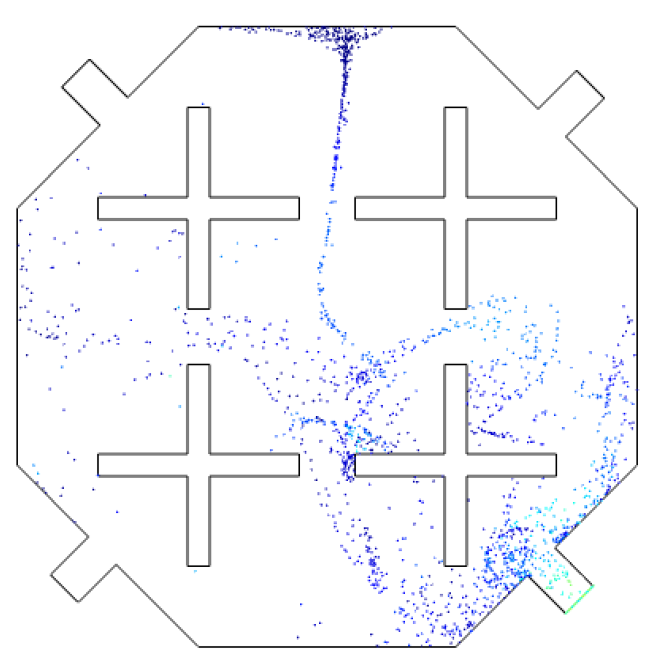
Velocity plot at t=2.0s



Pressure plot



Particle Tracing plot at t=1.0s



Particle Tracing plot at t=2.0s

Mixing Efficiency

In order to explain the microfluidic behavior inside the mixer, we need to find the optimal flow operation conditions by:

$$\varepsilon_{\text{mixing}} = 1 - \frac{1}{w}\int_0^w \left| \frac{X_{Ax,outlet} - 0.5}{X_{Amax} - 0.5} \right| dx \quad (1)$$

where X_{Amax} is the maximum mole fraction of fluid A, $X_{AX,outlet}$ is the mole fraction of fluid A at the outlet, W=1mm denotes the outlet width. Reynolds number is calculated by:

$$\mathrm{Re} = \frac{\rho V_0 W}{\mu} \quad (2)$$

where ρ is the density of fluid; V_0 is the average velocity of the inlet channel; W=0.35mm is the width of inlet and outlet channels; μ is the dynamic viscosity of the working fluid. So, governing equations during the mixing process can be obtained by solving the continuity, momentum and diffusion equations, to come up with:

$$\frac{\partial V}{\partial t} + V * \nabla V = -\nabla p + \frac{1}{Re}\nabla^2 V \quad (3)$$

Conclusion and Future Work

In this poster, an active microfluidic mixer with fully-differential rotary blades is designed and simulated by COMSOL. Its laminar flow behavior is traced by particle tracing simulation. Simulation results show that fully-differential actuation scheme of the blades lead to effective mixing of the microfluids. In the future, we will work on finding the optimized rotary speed/direction combinations for the four blades to achieve the best mixing efficiency.

References

1. COMSOL: MEMS Module Model Library, Multiphysics: MEMS Module.
2. Wang, C.-T., Hu, Y.-C., & Hu, T.-Y., “Biophysical Micromixer”, Sensors, Volume 9, Issue 7, pp. 5379–5389, 2009.